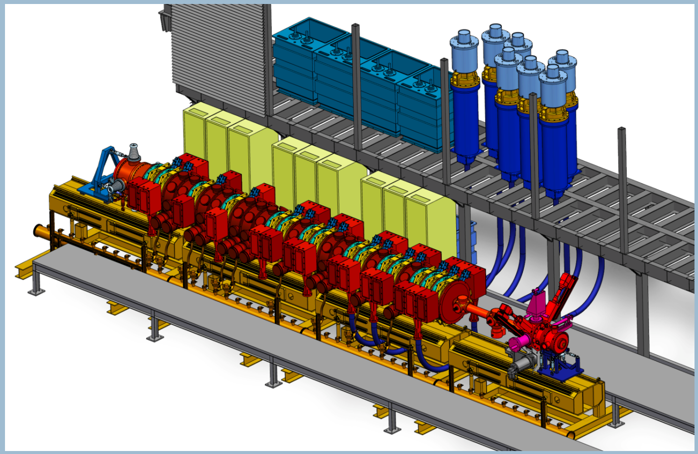
Status of NDCX-II, a short-pulse ion accelerator for ion beam-driven physics studies*



A. Friedman, J. J. Barnard, R. H. Cohen, M. Dorf, D. P. Grote, S. M. Lund, W. M. Sharp, *LLNL*

A. Faltens, E. Henestroza, J.-Y. Jung, J. W. Kwan, E. P. Lee, B. G. Logan, J. H. Takakuwa, J.-L. Vay, W. L. Waldron, *LBNL*

R. C. Davidson, E. P. Gilson, I. D. Kaganovich, *PPPL*

Paper TO7.10, 52nd Annual Meeting of the APS Division of Plasma Physics
Chicago, November 11, 2010

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Fusion Energy Sciences

Heavy Ion Fusion Science Virtual National Laboratory

BERKELEY LAB

PPPL PRINCETON PLASMA PHYSICS LABORATORY

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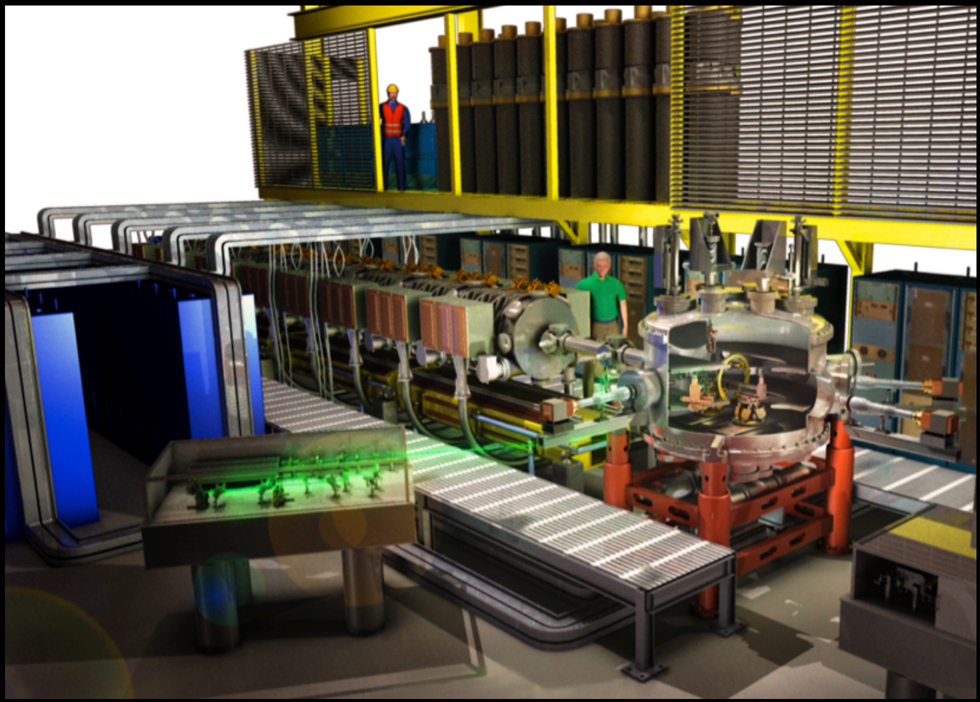
Neutralized Drift Compression Experiment-II (NDCX-II)

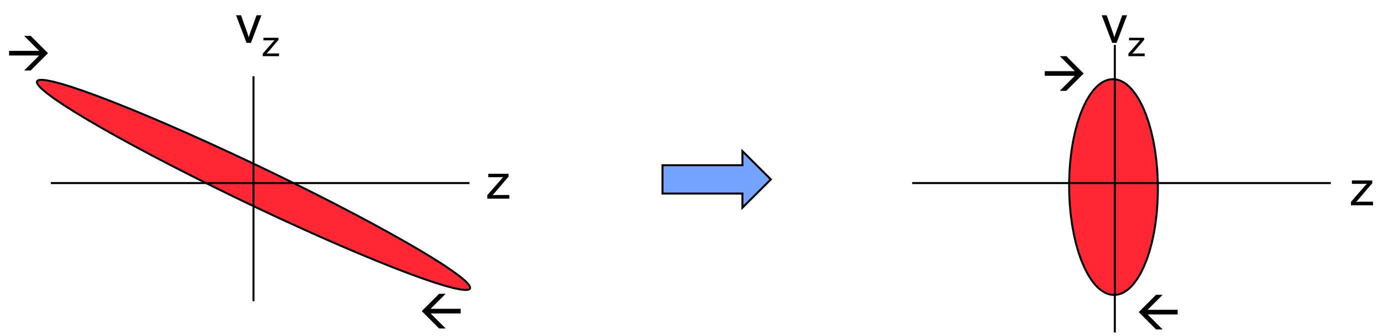
- A novel pulse-compressing ion induction accelerator
- Uses many parts from LLNL's ATA (which accelerated electrons)
- A user facility for studies of:
  - warm dense matter physics
  - heavy-ion-driven target physics
  - intense-beam dynamics



- Construction of the $11M initial configuration began in July, 2009,
- Project completion is due by March, 2012; aiming for fall of 2011.
- Commissioning will then begin, followed by target experiments.

The "drift compression" process is used to shorten an ion bunch

- Induction cells impart a head-to-tail velocity gradient ("tilt") to the beam.
- The beam shortens as it moves down the beam line (pictures in beam frame):



Initial beam, with velocity tilt

compressed beam

- Space charge, if present, limits this compression.
- To obtain a short pulse on target, we introduce neutralizing plasma; this is neutralized drift compression.

The drift compression concept is used twice in NDCX-II

Initial non-neutral pre-bunching for:

- better use of induction-core Volt-seconds
- early use of 70-ns 250-kV Blumlein power supplies from ATA

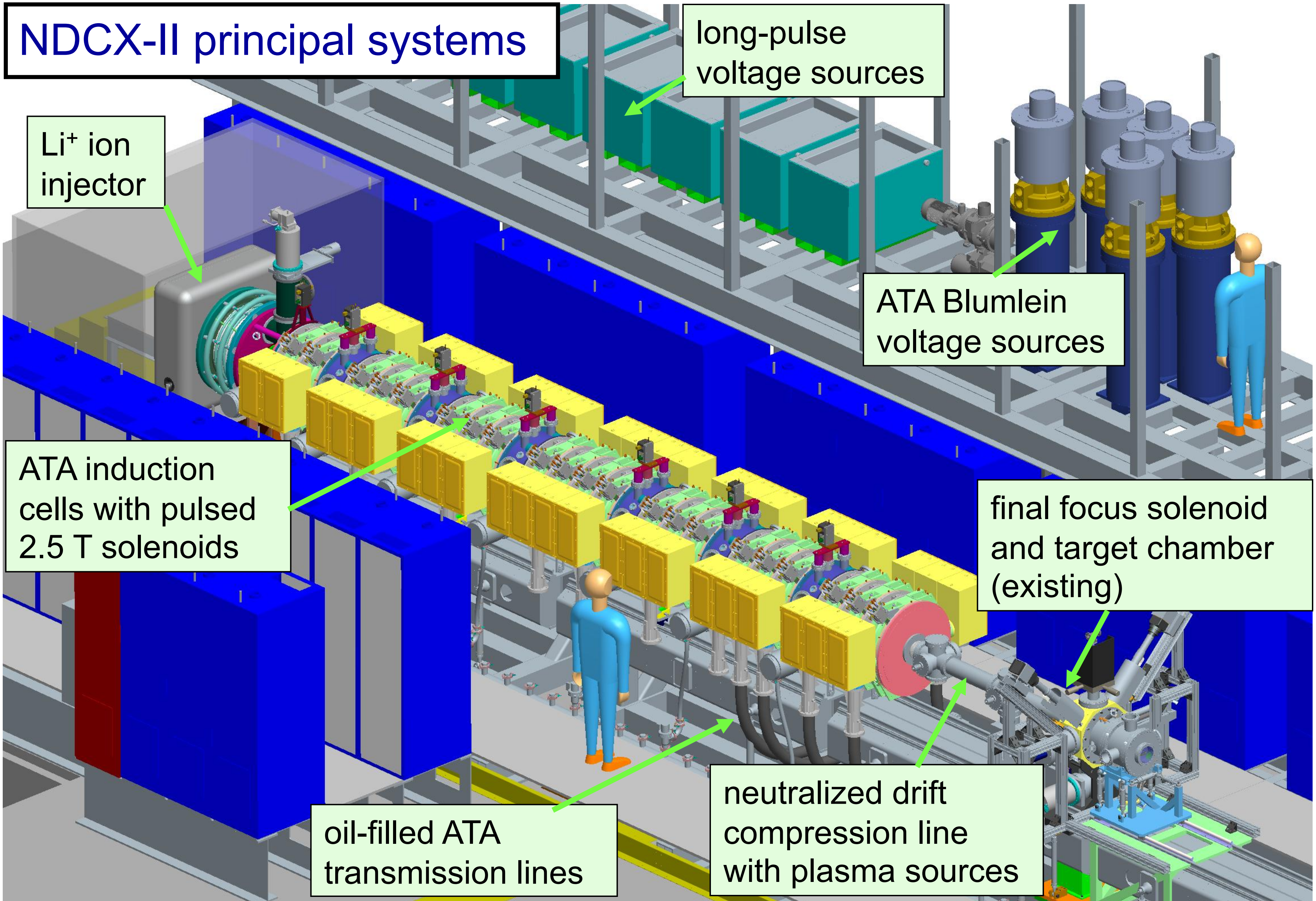
inject → apply tilt → drift → accelerate → apply tilt → neutral-ized drift → target

Final neutralized drift compression onto the target

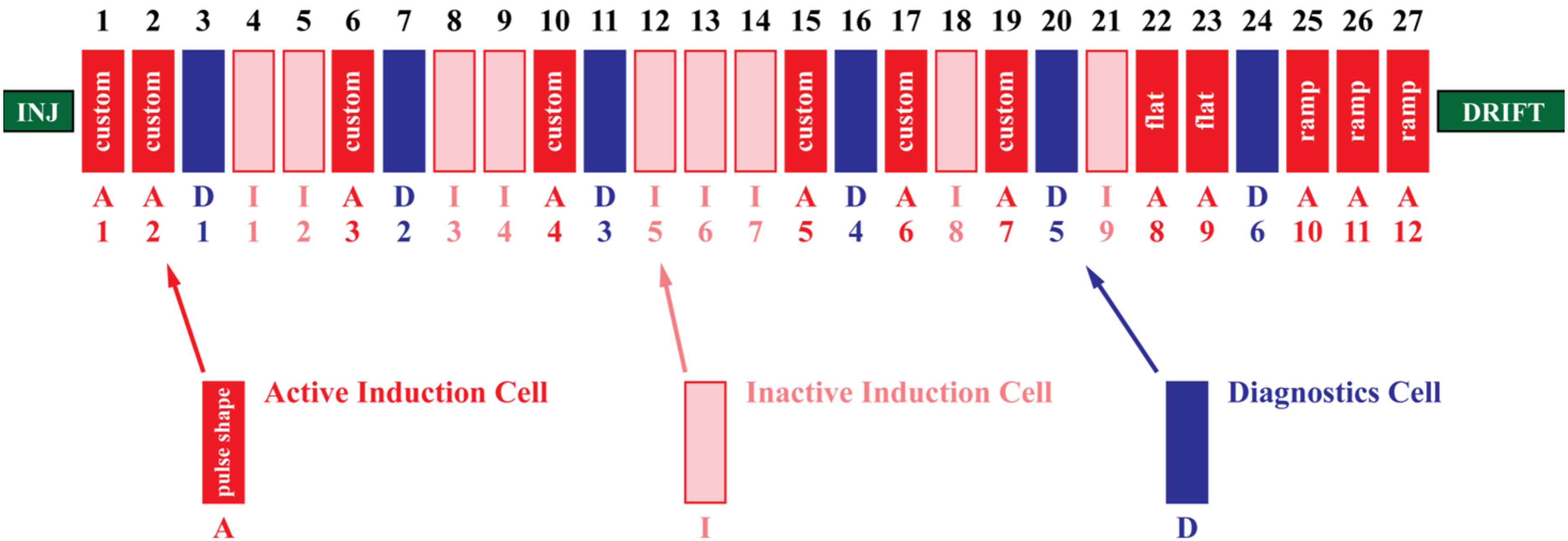
- Electrons in plasma move so as to cancel the beam's electric field
- Require $n_{plasma} > n_{beam}$ for this to work well

See: A. Friedman, *et al.*, *Phys. Plasmas* **17**, 056704 (2010).

NDCX-II principal systems



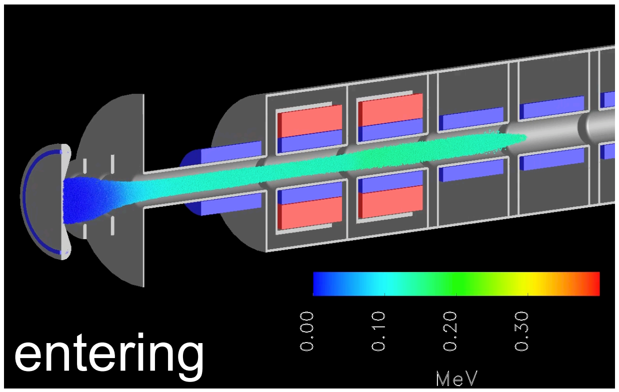
The baseline hardware configuration is as presented during the April 2010 DOE Project ("Lehman") Review

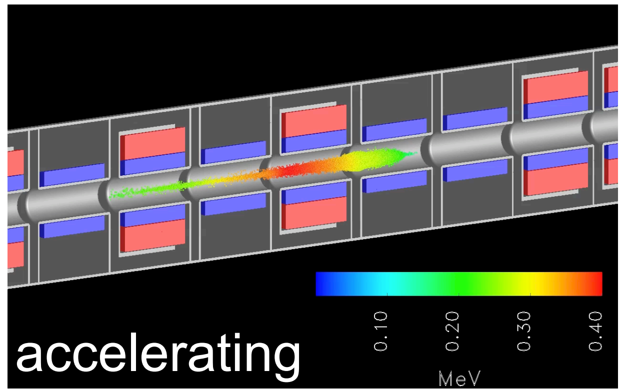


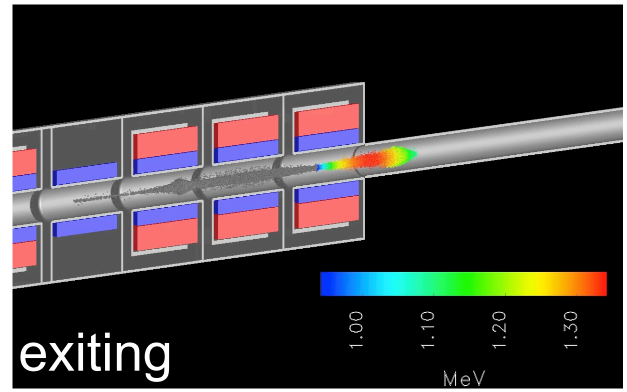
- 27 "lattice periods" after the injector
- 12 active induction cells
- Beam charge ~50 nano-Coulombs
- FWHM < 1 ns
- Kinetic energy ~ 1.2 MeV

Simulations enabled development of the NDCX-II physics design

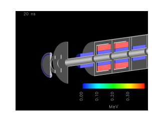
- Space-charge-dominated ion beams are non-neutral plasmas — a self-consistent kinetic description is necessary







- New, fast 1-D (longitudinal) particle-in-cell code ASP enabled finding an attractive operating point within the large parameter space
- Injector, transverse beam confinement, and final focusing were developed using the Warp code in (r,z) geometry
- We used 3-D Warp calculations to assess performance in the presence of imperfections, set tolerances



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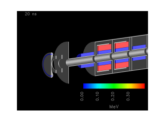

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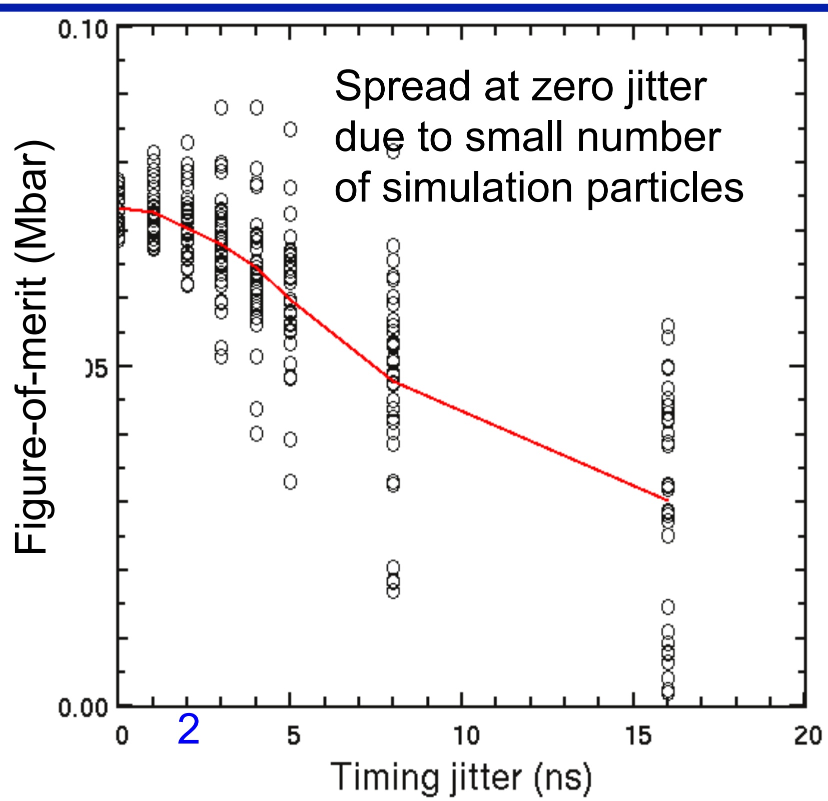
40ga24-12

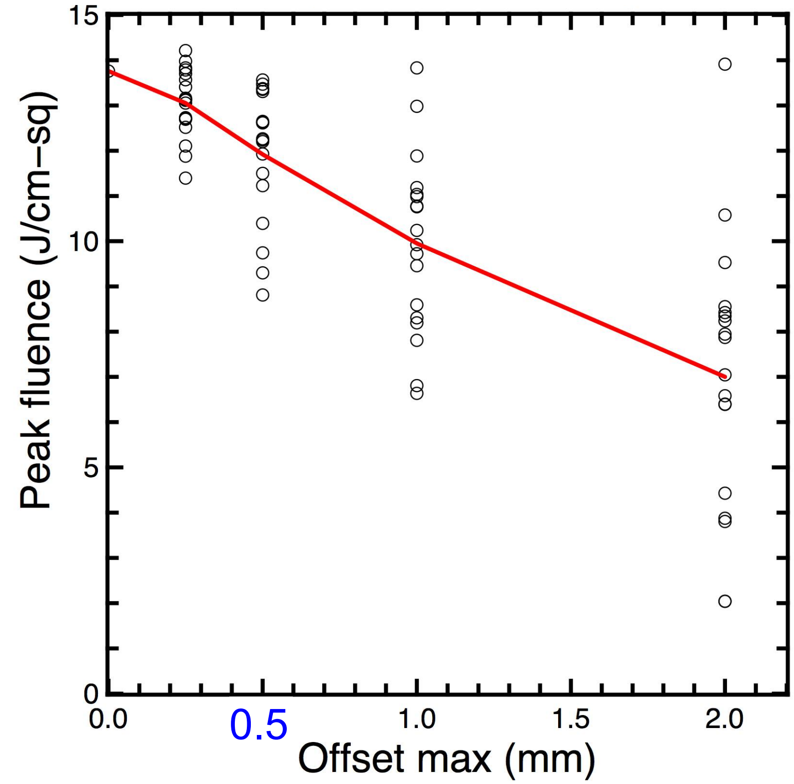
Ensembles of Warp runs indicate only minor degradation due to:

pulser timing jitter / magnet misalignment



- Random timing shifts were imposed on the accelerating voltage pulses.
- Nominal NDCX-II spark-gap jitter is 2 ns

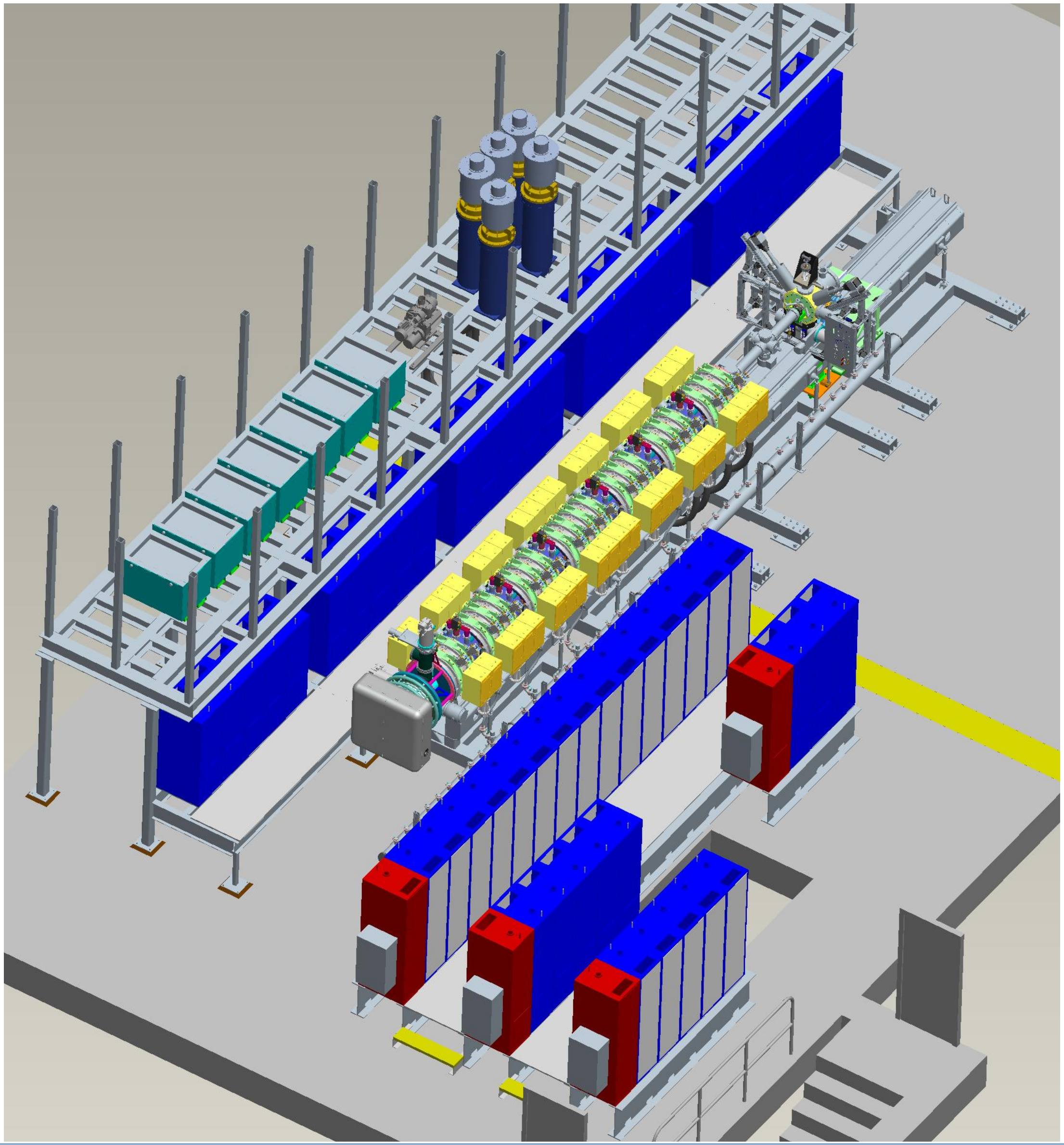
40g-12



- Random offsets were imparted to the solenoid ends.
- Nominal NDCX-II tolerance is 0.5 mm
- Beam "steering" via dipole magnets will center beam and minimize "corkscrew" distortion.

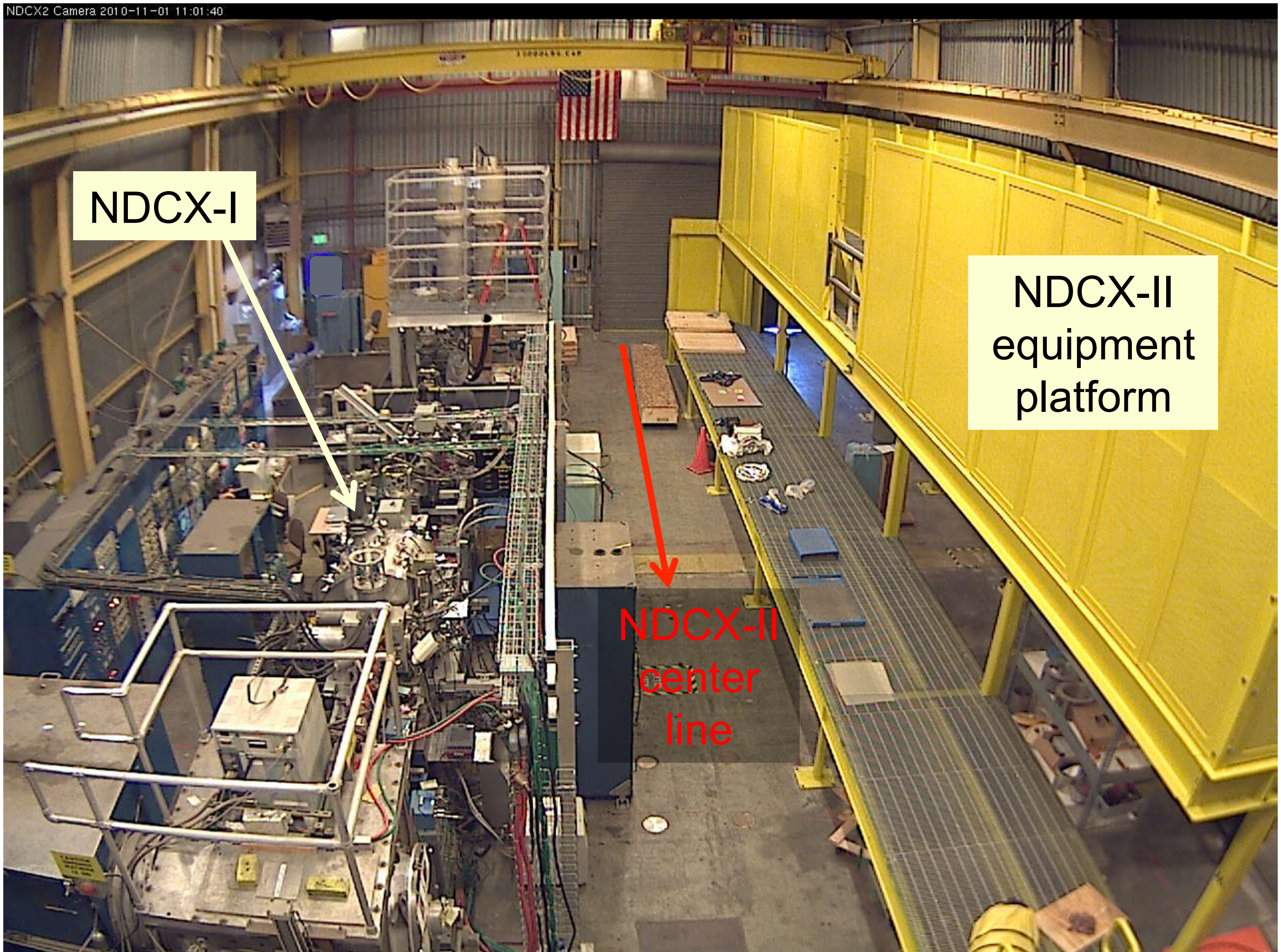
35g-15 (older 15-cell design)

Project status

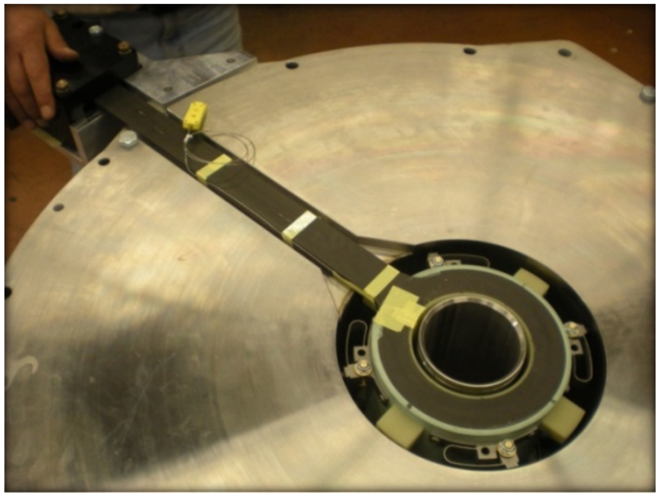


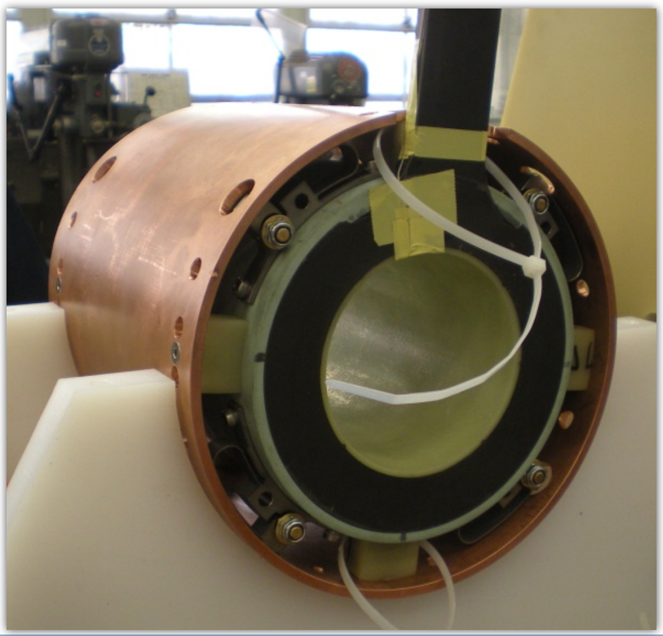
- Equipment platform has been installed
- Accelerator support structure has been received
- All needed ATA cells have been modified
- Solenoids are being wound and potted
- Injector is in detailed design

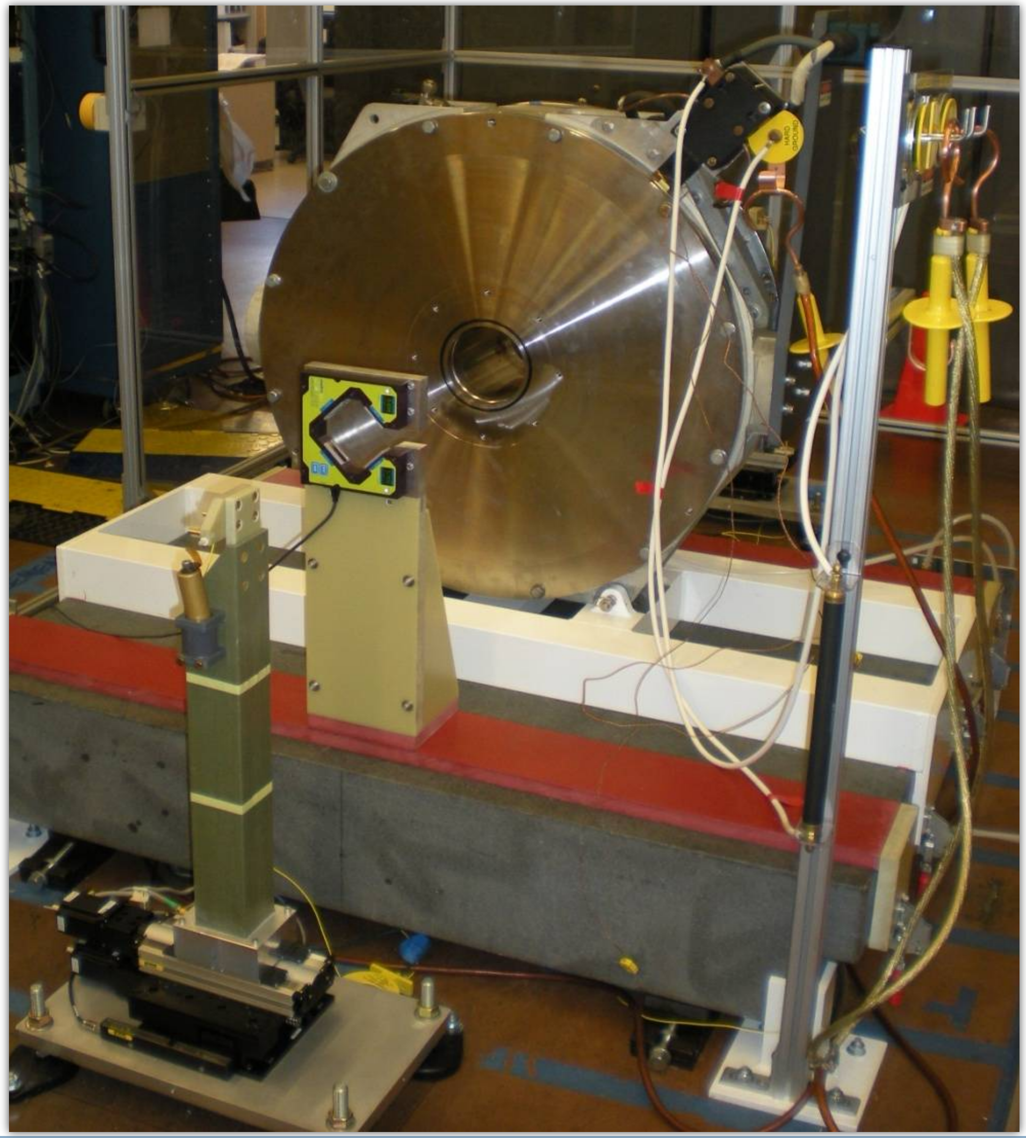
LBNL Building 58, as viewed from webcam on Nov 1, 2010



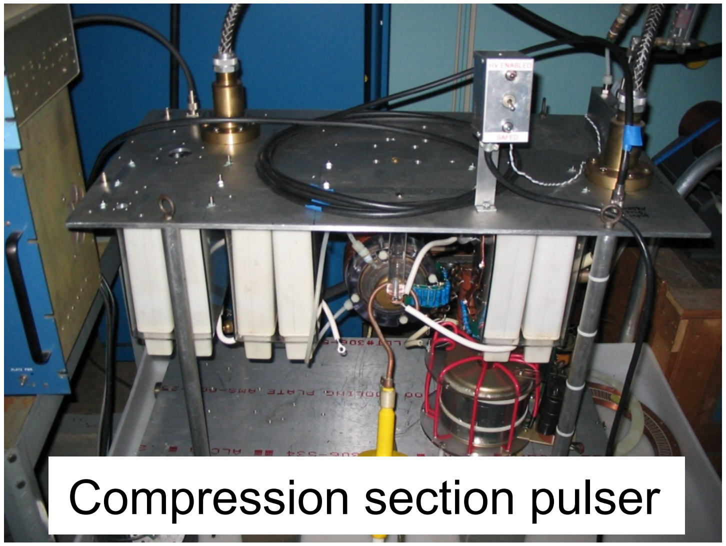
Accelerator induction cell, solenoid, magnet measurement stand



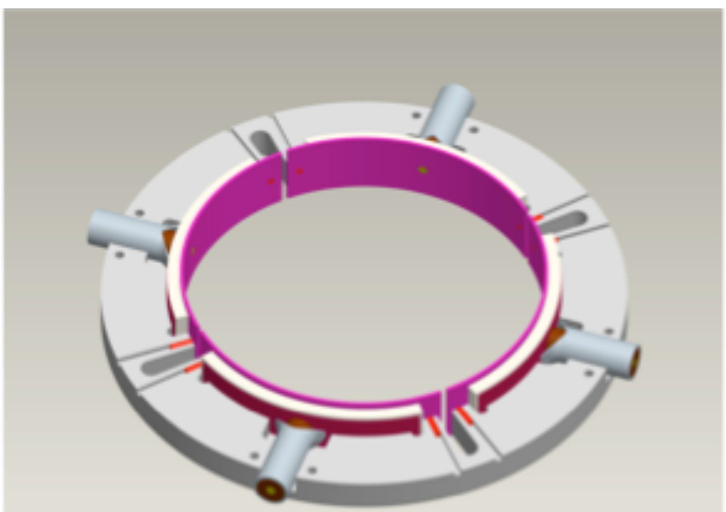




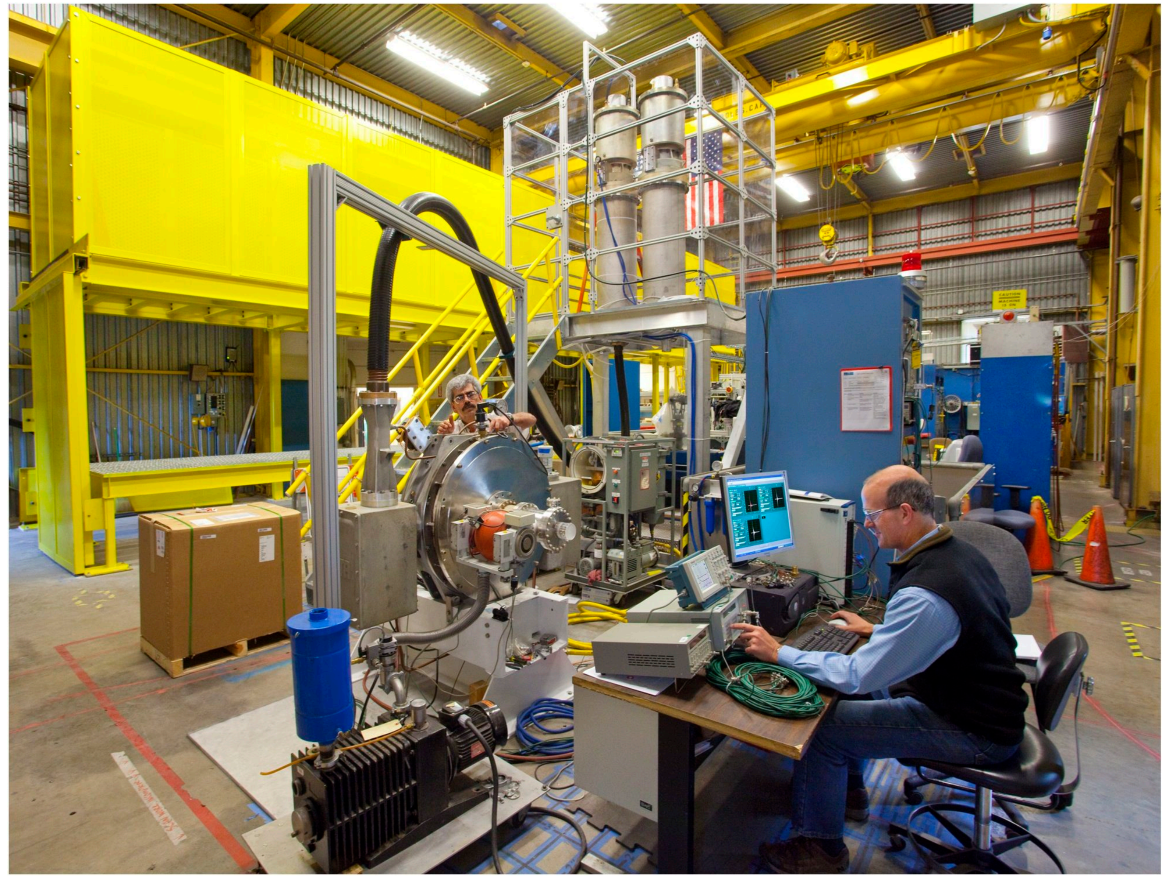
The NDCX-II test stand is used to test compression section pulsers and beam position monitors



Compression section pulser

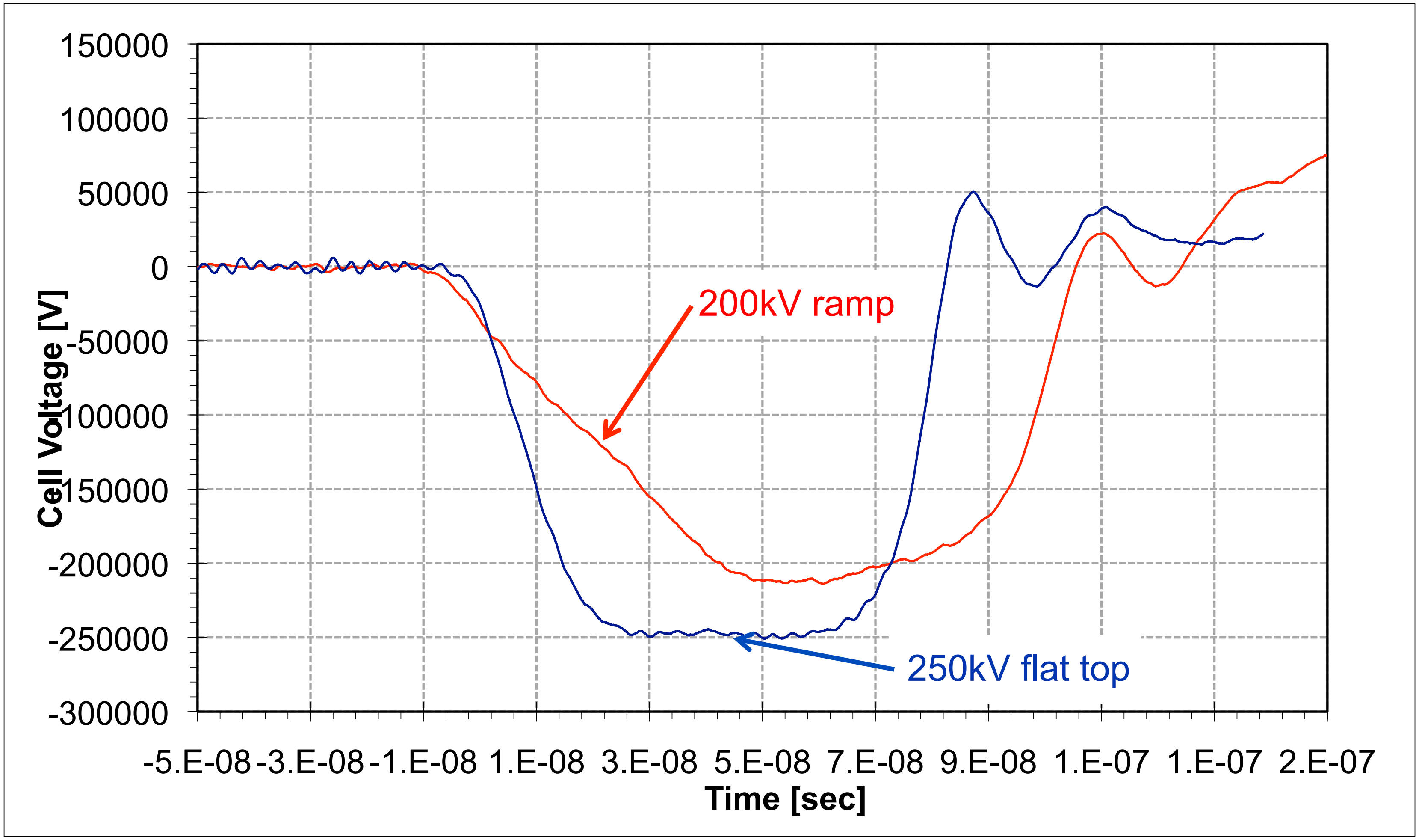


Beam position monitor assembly



NDCX-II test stand

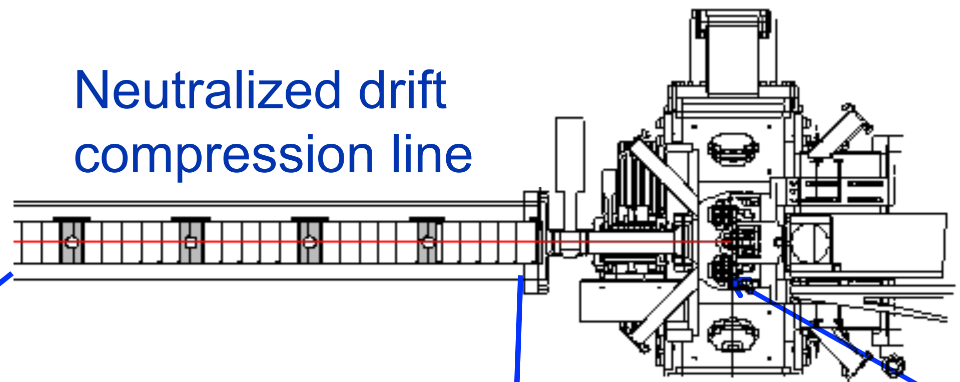
Flat top and ramped voltage waveforms generated on the test stand were used in the physics design

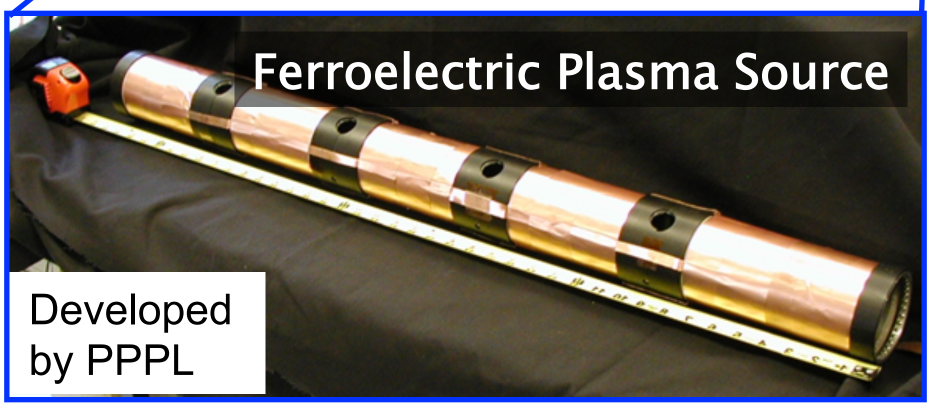


NDCX-II plasma sources are based on NDCX-I experience

Target chamber

Neutralized drift compression line



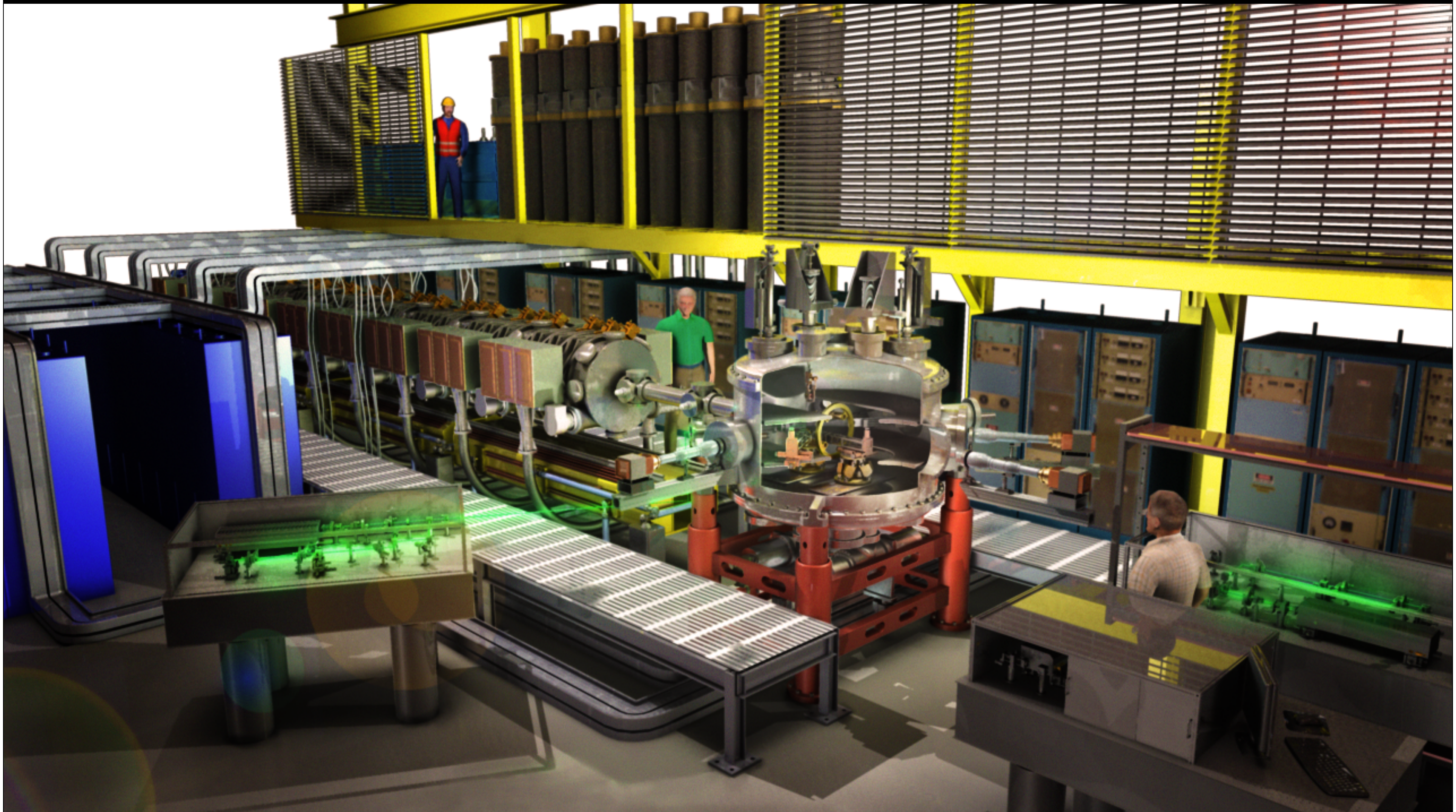


NDCX-II will be far more capable than NDCX-I

	NDCX-I (typical bunched beam)	NDCX-II 12-cell (r,z simulation)
Ion species	K^+ (A=39)	Li^+ (A=7)
Total charge	15 nC	50 nC
Ion kinetic energy	0.3 MeV	1.2 MeV
Focal radius (containing 50% of beam)	2 mm	0.6 mm
Bunch duration (FWHM)	2 ns	0.6 ns
Peak current	3 A	36 A
Peak fluence (time integrated)	0.03 J/cm^2	13 J/cm^2
Fluence within 0.1 mm diameter spot and 2 x FWHM duration		9.2 J/cm^2
Fluence within 50% focal radius and 2 x FWHM duration	0.014 J/cm^2	1.8 J/cm^2

NDCX-II estimates are from (r,z) Warp runs (no misalignments), and assume 1 mA/cm^2 emission, no timing or voltage jitter in acceleration pulses, no jitter in solenoid excitation, perfect neutralization, and a uniform non-depleted source; they also assume no fine energy correction (e.g., tuning the final tilt waveforms)

NDCX-II will be a unique user facility for warm dense matter, IFE target physics, and intense-beam physics.



NDCX II

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